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# EVALUATION OF SLEEVE GUN EFFECTIVENESS IN REPELLING ADULT STRIPED BASS

by

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This reports documents tests of the effectiveness of low-frequency sounds produced by a sleeve gun in redistributing adult striped bass (Morone saxatilis) in net pens in the forebay of John H. Kerr Dam, Virginia. Behavioral observations and statistical analyses indicated that adult striped bass in 20- by 4- by 4-ft (6.1- by 1.2- by 1.2-m) pens exhibited only subtle and inconsequential responses to sounds produced by a 150-cu3 sleeve gun. Startle responses were apparent only early in the tests, and fright responses, that would have been suggested by increased swimming speeds or strong directional movements away from the sound source, were never observed.

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## Preface

This report was prepared by the Water Quality Modeling Group (WQMG), Ecosystem Research and Simulation Division (ERSD), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), for the US Army Engineer District, Wilmington, Wilmington, NC, under Intra-Army Order for Reimbursable Services No. CESAW-PD-E-90-19, 6 April 1990. Mr. Frank Yelverton, Wilmington District, managed the study.

The report was prepared by Mr. Gene R. Ploskey, Dr. John M. Nestler, and Mr. James L. Pickens of WES. The work was conducted under the general supervision of Dr. Mark S. Dortch, Chief, WQMG; Mr. Don L. Robey, Chief, ERSD; and Dr. John Harrison, Chief, EL.

Participants in the experiments included Mr. Bill Blakeley (Seismar Systems and Services, Inc.); Messrs. Michael Duval, Bud LaRoche, Bill Kittrell, Carroll Carwile, and David Thompson (Virginia Department of Game and Inland Fisheries); and Messrs. John Fulton, York Grow, and Erik Edwardson (John H. Kerr Project, US Army Corps of Engineers). John Field, Resource Manager, Kerr Lake Project, and members of his staff provided equipment and logistical support. Adult striped bass were provided by Messrs. Scott Van Horn, Wayne Jones, and Bill Collart of the North Carolina Wildlife Resources Commission and by the Virginia Department of Game and Inland Fisheries through arrangements made by Mr. Bill Kittrell. Ms. Rhonda Lofton of the WQMG digitized plots of frequency spectra for use in the report.

Commander and Director of WES during publication of the report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

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# Contents

## Conversion Factors, Non-SI to SI (Metric) Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric units) as follows:

| Multiply | By | To Obtain |
|---|---|---|
| acres | 4,046.873 | square meters |
| cubic feet | 0.02831685 | cubic meters |
| degrees (angle) | 0.01745329 | radians |
| feet | 0.3048 | meters |
| inches | 2.54 | centimeters |
| pounds (force) per square inch | 6.894757 | kilopascals |

# EVALUATION OF SLEEVE GUN EFFECTIVENESS
# IN REPELLING ADULT STRIPED BASS

## Introduction

John H. Kerr Reservoir is a 50,000-acre[*] impoundment on the Roanoke River, and the dam is near Boydton, VA. The reservoir has a land-locked population of striped bass with an estimated spawning population of 90,000 fish.

Mortality of large striped bass during passage through the hydropower turbines of Kerr Dam occurs sporadically in spring or early summer of years when flows are above-average in the Roanoke River. The Wilmington District (SAW), the North Carolina Wildlife Resources Commission, and the Virginia Department of Game and Inland Fisheries have all expressed concern over these losses. In late spring and early summer 1989, the Virginia Department of Game and Inland Fisheries (VDGIF) recovered 358 dead or dying striped bass that had passed through the turbines of Kerr Dam, and the VDGIF estimated that 5,000 were killed in 1982. The SAW has begun to evaluate the problem and to assess a variety of ameliorative alternatives.

This report documents net pen tests of the effectiveness of a sound source (i.e., a sleeve gun commonly used in geologic exploration) in repelling adult striped bass (Morone saxatilis). A sleeve gun was selected as a promising technology for repelling adult striped bass because it produces a sound spectra in the range that the New York Power Authority (NYPA) found effective in repelling young-of-year white perch (Morone americana) and striped bass (Normandeau Associates and Sonalysts 1990). The NYPA found that pure tones at very low frequencies (25 Hz) and high source levels (200 dB re 1 $\mu$Pa) elicited strong avoidance responses in these fishes.

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\* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

A sleeve gun is a mechanical device that is filled with compressed air and fired to produce omni-directional low frequency, high amplitude sounds. If effective in repelling adult striped bass, a sleeve gun would offer a relatively low-cost alternative for reducing entrainment compared to constructing structural barriers or producing repelling sounds electronically.

## Methods

All tests were performed in the forebay of John H. Kerr Lake near the buoy line on May 2 and 3, 1990. Four floating 20-ft long, 4-ft-wide, 4-ft-deep net pens, made of 1/4-in. tar-coated nylon webbing, were suspended from floating 3-in.-diam PVC pipe. The bottom of each pen was visually divided into four quadrants by a PVC frame outlining four 4- by 5-ft areas. The bottom frame was covered with white bolting cloth and suspended 3-ft deep in each pen. The bolting cloth provided contrast to increase the visibility of fish for four observers, each assigned to monitor fish in one pen. Quadrants were numbered consecutively from one to four (i.e., Q1, Q2, Q3, and Q4) so that observers could associate counts of fish with specific areas of each pen.

Thirty one adult striped bass were collected from the Roanoke River and other areas in Virginia and transported to the forebay of John H. Kerr Dam on April 30 and May 1. Most fish had been spawning or were ready to spawn when captured. They were distributed among the four nets and held 22 to 48 hr before testing. All fish were measured and those that died during the study were weighed. Weights of surviving striped bass were estimated by a length-weight relation for striped bass [log(grams) = -4.924 + 3.007 log(mm)] to minimize handling before they were released.

Before striped bass were tested, we recorded ambient low-frequency sounds in the forebay and sounds from many blasts of the sleeve gun to obtain an average source level (i.e., sound

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intensity 1 m from the source) and its frequency spectrum. Sound pressure levels presented in this report are all expressed in dB referenced to 1 $\mu$Pa. These measurements were made in the forebay on June 1 using a URSD Type F42 Model D hydrophone and Hewlett Packard Model 3582A spectrum analyzer.

Net pens were tied together in a raft with two flat-bottom boats, which served as platforms for observers (Figure 1). A 150-cm$^3$ sleeve gun weighing 59 kg was deployed from a boom mounted on the front of a 7.3-m-long pontoon boat and was positioned from 2.3 to 15.2 m from the front of the net pens at depths ranging from 5 to 9 m. The gun could not be deployed <5 m deep because of air venting, which significantly reduced the pressure wave from the gun. Net pens were oriented so that Q1 of every pen was always closest to the sleeve gun and successive quadrants were further away. The sleeve gun was recharged from a cascade of compressed air from eight 1.8 ft$^3$, air bottles charged to about 2700 PSI. We monitored low-frequency sounds from the sleeve gun by placing a hydrophone in a net pen in the center of the raft at the end nearest the sleeve gun (Q1).

We conducted seven tests of various designs (Table 1). The first test was a soundless control in which the distribution of fish among quadrants of every pen was recorded 5 sec before and 5, 10, 15, 20, 30, 40 sec after a simulated firing every minute for 15 min. In Tests 2 through 7, observers recorded the distribution of fish among quadrants 5 sec before and 5, 10, 15, 20, 30, and 40 sec after every blast of the gun. Firing was at 1-min intervals for 4 to 15 min per test. In Table 1, horizontal range is the distance along the surface of the water from the front of the net pens to the cable deploying the sleeve gun. Range refers to the distance from the gun to the front of the net pens. Theoretical sound level is sound intensity expected at the end of the pens nearest the gun based upon source levels and sound losses due to spreading and attenuation of sound in water.

Net pen
with 4
quadrants

Boats with two
observers each

4

3

2

1
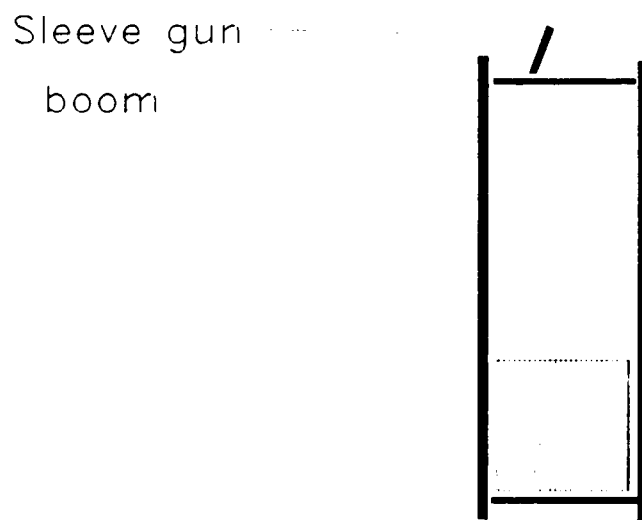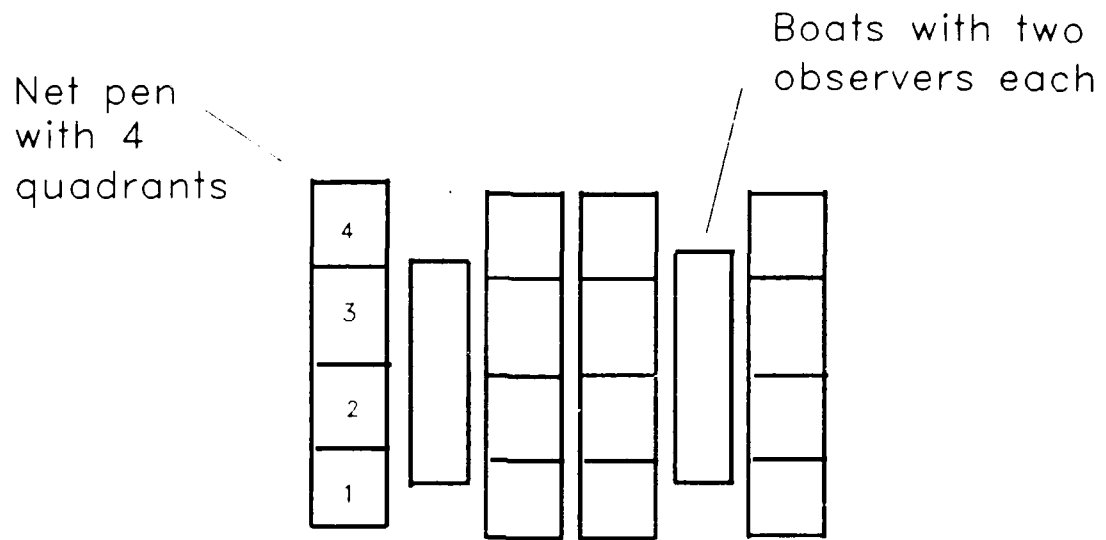
Sleeve gun
boom

Pontoon boat

Figure 1. Diagram showing the plan view of boats and net
pens in sleeve gun experiments at Kerr Lake, VA

Actual sound level is sound intensity measured with a hydrophone at the end of the pens nearest the sleeve gun.

Table 1

Experimental Design Of Seven Tests Performed In The Forebay Of John H. Kerr Dam, VA

| LAKE | YEAR | MONTH | DAY | TEST | TYPE | START TIME | DURATION (Min.) | SLEEVE PRESSURE (psi) | GUN DEPTH (m) | WATER DEPTH (m) | HORIZ. RANGE (m) | RANGE (m) | SOURCE LEVEL (dB) | SOUND LEVEL (dB) | SOUND LEVEL (dB) |
|------|------|-------|-----|------|------|-----------|------------------|------------------------|----------------|------------------|-------------------|------------|--------------------|-------------------|-------------------|
| KERR | 1990 | 5 | 2 | 1 | CONTROL | 1143 | 15 | 0 | 5 | 10.6 | 15.2 | 16.0 | 0 | 0 | 0 |
| KERR | 1990 | 5 | 2 | 2 | FIRING | 1215 | 15 | 1500 | 5 | 10.6 | 15.2 | 16.0 | 200 | 176 | 173 |
| KERR | 1990 | 5 | 2 | 3 | FIRING | 1235 | 7 | 2000 | 7 | 10.6 | 15.2 | 16.7 | 200 | 175 | 175 |
| KERR | 1990 | 5 | 2 | 4 | FIRING | 1252 | 4 | 1875 | 7 | 10.6 | 15.2 | 16.7 | 200 | 175 | --- |
| KERR | 1990 | 5 | 2 | 5 | FIRING | 1630 | 14 | 1500 | 5 | 26.8 | 15.2 | 16.0 | 200 | 175 | 173 |
| KERR | 1990 | 5 | 3 | 6 | FIRING | 0930 | 15 | 1500 | 9 | 26.8 | 2.3 | 9.3 | 200 | 180 | 174 |
| KERR | 1990 | 5 | 3 | 7 | FIRING | 1100 | 14 | 1500 | 8 | 26.8 | 4.3 | 9.1 | 200 | 180 | 175 |

We tested for significant changes in distributions of striped bass in pens in several ways. Observers were asked to qualitatively assess the behavior of striped bass after the sleeve gun was fired. Statistical tests were performed on data from three time frames of every test because we were concerned about possible bias associated with reduced responsiveness of fish to successive blasts in full 14- to 15-min tests. First, we examined changes in density among quadrants in the first minute of every test (hereafter referred to as "1-min tests") and used data from different pens as replicate samples. These tests had the fewest degrees of freedom but included data collected when fish should have been most responsive. Second, analyses of data collected in the first 5 min of every test (4 min in Test 4) were deemed "5-min tests." Third, data collected throughout a test were analyzed as "full tests." In 5-min and full tests, data collected in successive 1-min periods were treated as replicate samples because we could not detect significant differences in mean density per quadrant among periods.

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In all three time frames, we performed chi-square tests on two-way contingency tables of density per quadrant versus time (5 sec before and 5, 10, 15, 20, 30, and 40 sec after every blast) to determine whether distributions changed significantly. We used two-way analysis of variance by test to examine time and quadrant effects as well as pen and quadrant effects and any interactions. We also used analysis of variance to determine whether mean densities in single quadrants changed significantly with time. Statistical tests were considered to be significant at $\alpha = 0.05$ unless noted otherwise.

### Results

Twenty seven of the 31 striped bass tested (87%) were 660 to 740 mm long and weighed 3,500 to 5,500 g (Figure 2). The smallest was 451 mm long and the largest 762 mm long. In the first three tests, three pens contained eight fish each and one had seven. Two dead fish were removed before Tests four and five, resulting in a distribution of 8, 8, 7, and 6 fish among pens. Overnight mortalities reduced numbers to 5, 4, 4, and 6 fish in respective pens for Tests six and seven.

Preliminary testing of the sleeve gun indicated that an average source level of about 200 dB could be expected in certain frequency ranges and that sound level was well above ambient noise levels (signal to noise ratios >3). Source levels were 200 dB at 13 Hz, 185 to 191 dB at 10 to 12 Hz but only 175 to 181 dB at most other frequencies from 0 to 50 Hz when the gun was fired at a depth of 5 m (e.g., Figure 3). The frequency spectrum of the gun changed significantly when it was fired at depths of 7 to 9 m. Peak source levels near 200 dB occurred at frequencies of about 9, 37, and 39 Hz and most frequencies from about 27 to 50 Hz had source levels exceeding 191 dB (Figure 4). Relative to ambient sound readings (Figure 5), signal to noise ratios for a gun fired at a depth of 5 m were about 3:1 at 0 to 10 Hz, 40:1 at 10 to 13 Hz, 15:1 at 13 to 15 Hz and 10:1 at higher frequencies. Signal to noise ratios for a gun fired at a depth of 7 to 9 m
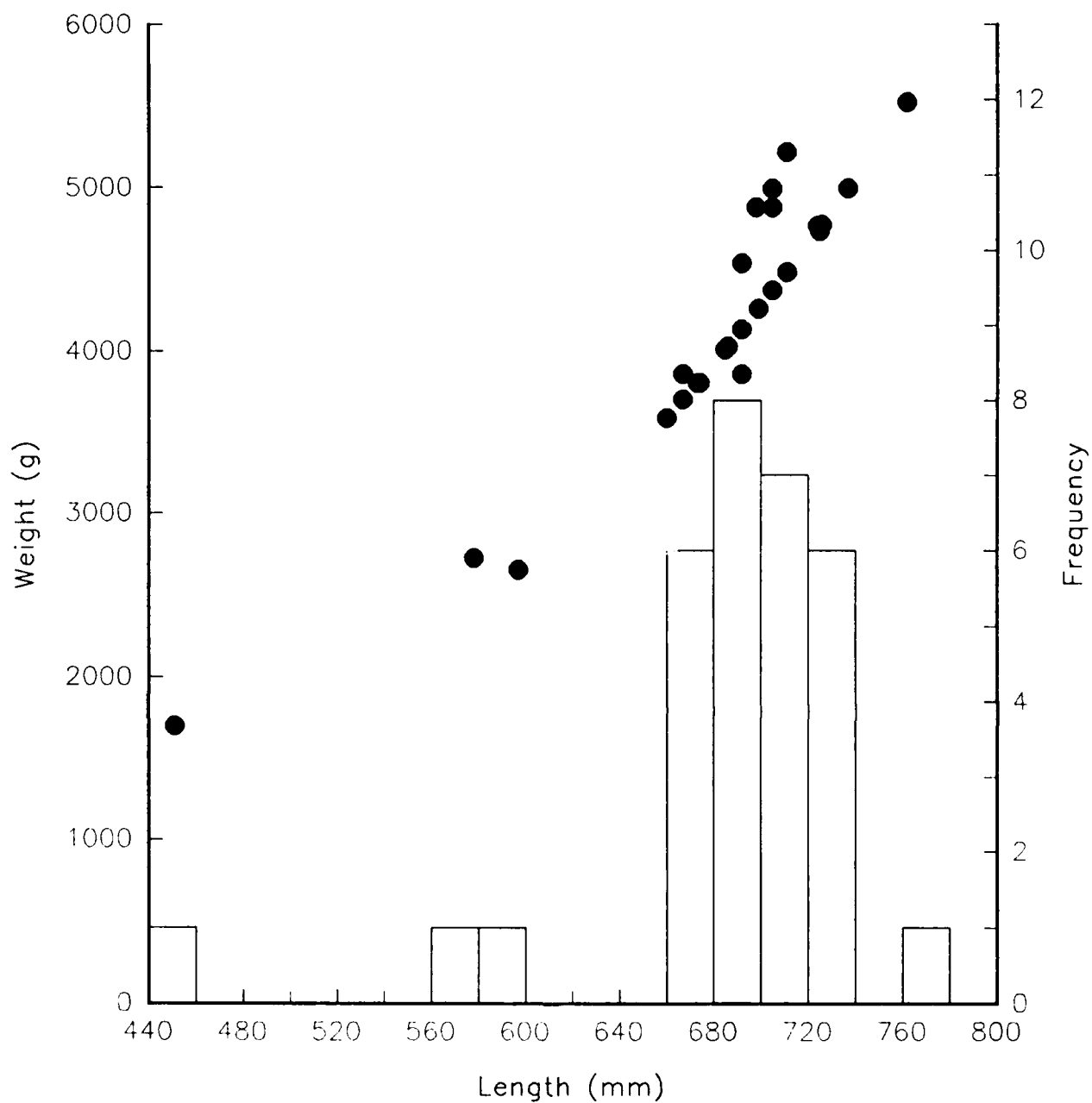
9

Figure 2. Length–weight relation (points) and length frequency histogram for adult striped bass used in tests of sleeve gun effectiveness at Kerr Lake, VA, in May 1990
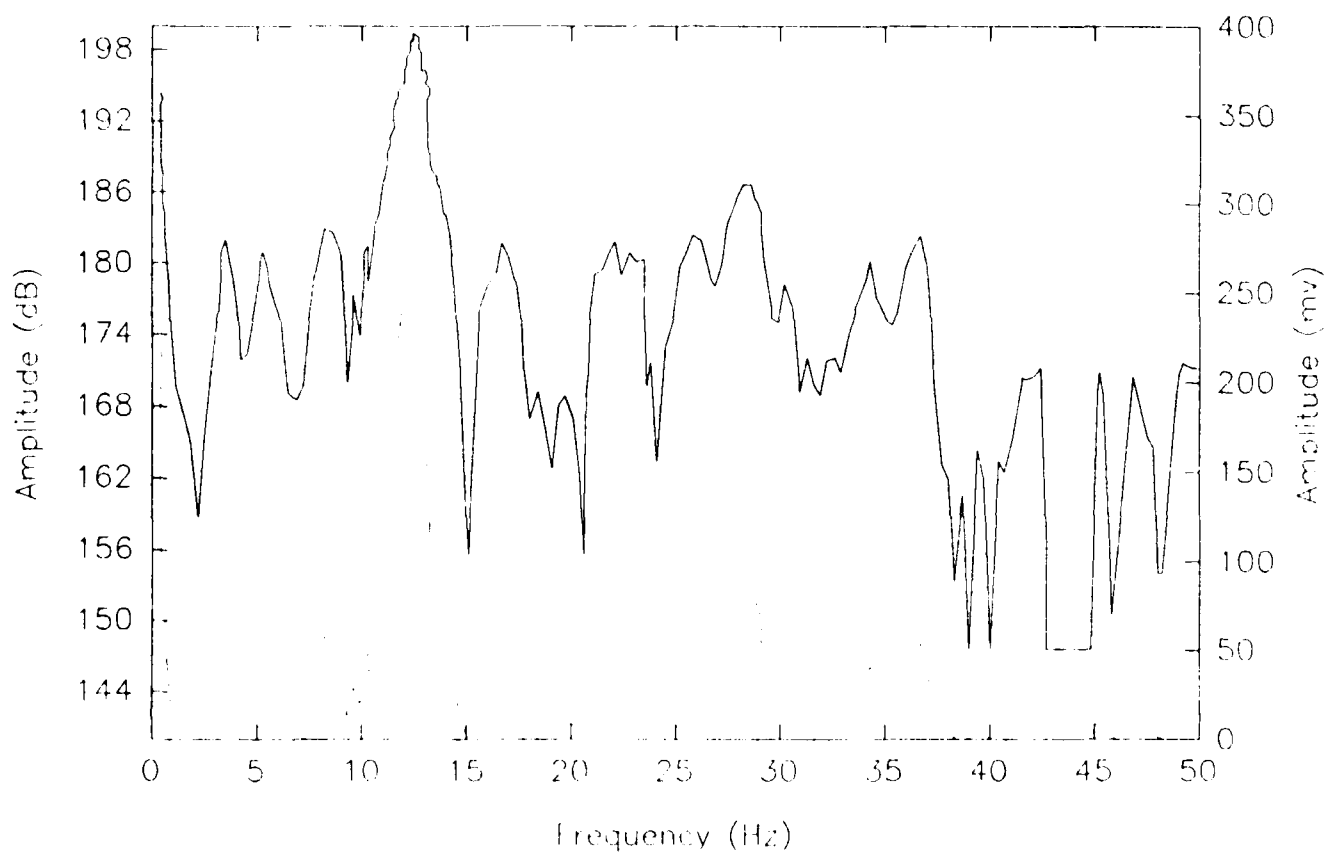
Figure 3. Frequency spectrum of source levels in dB (solid line) and mv (dotted line) transmitted from a sleeve gun blast 5 m deep in Kerr Dam Forebay
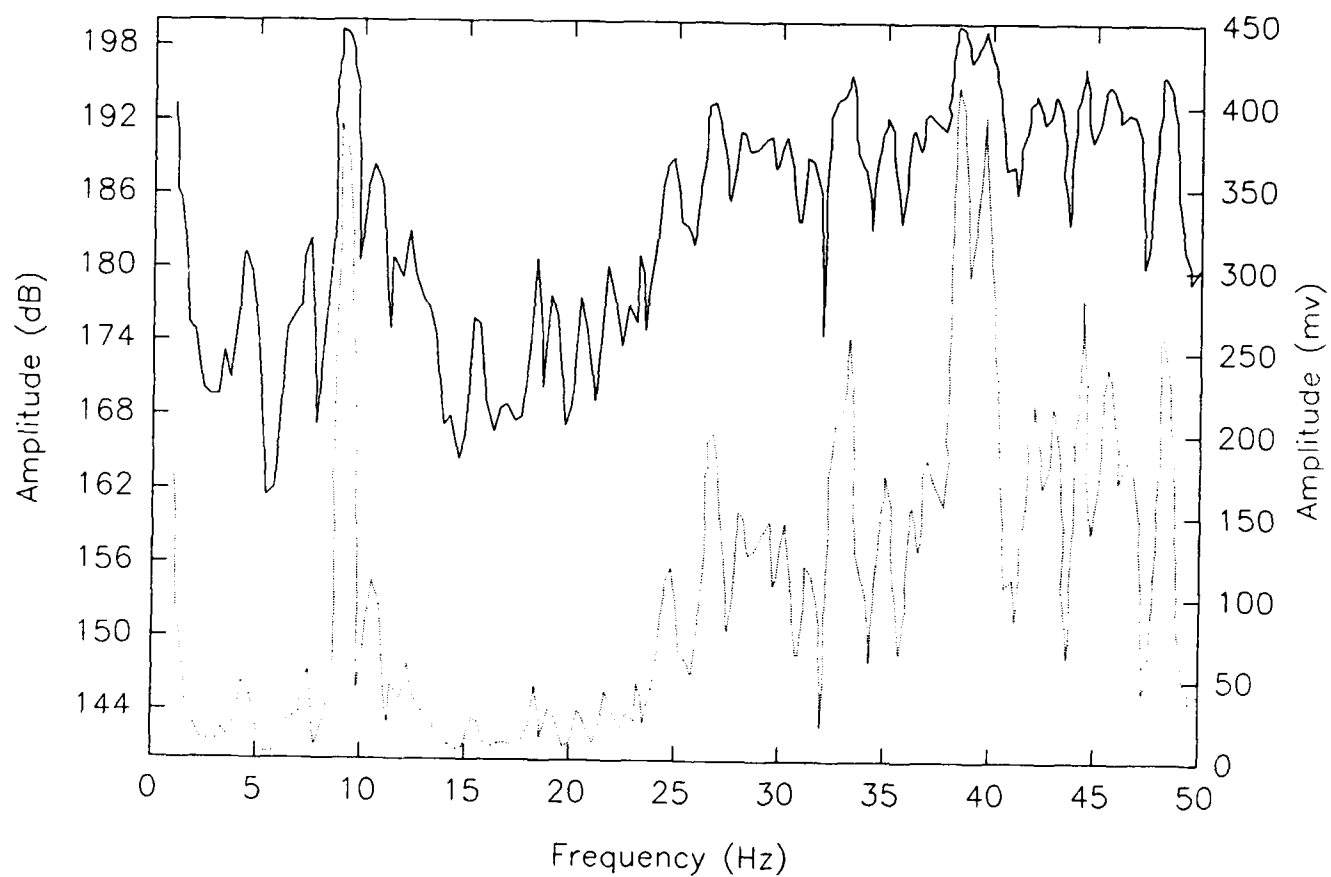
Figure 4. Frequency spectrum of source levels in dB (solid line) and
mv (dotted line) transmitted from a sleeve gun blast 9 m deep
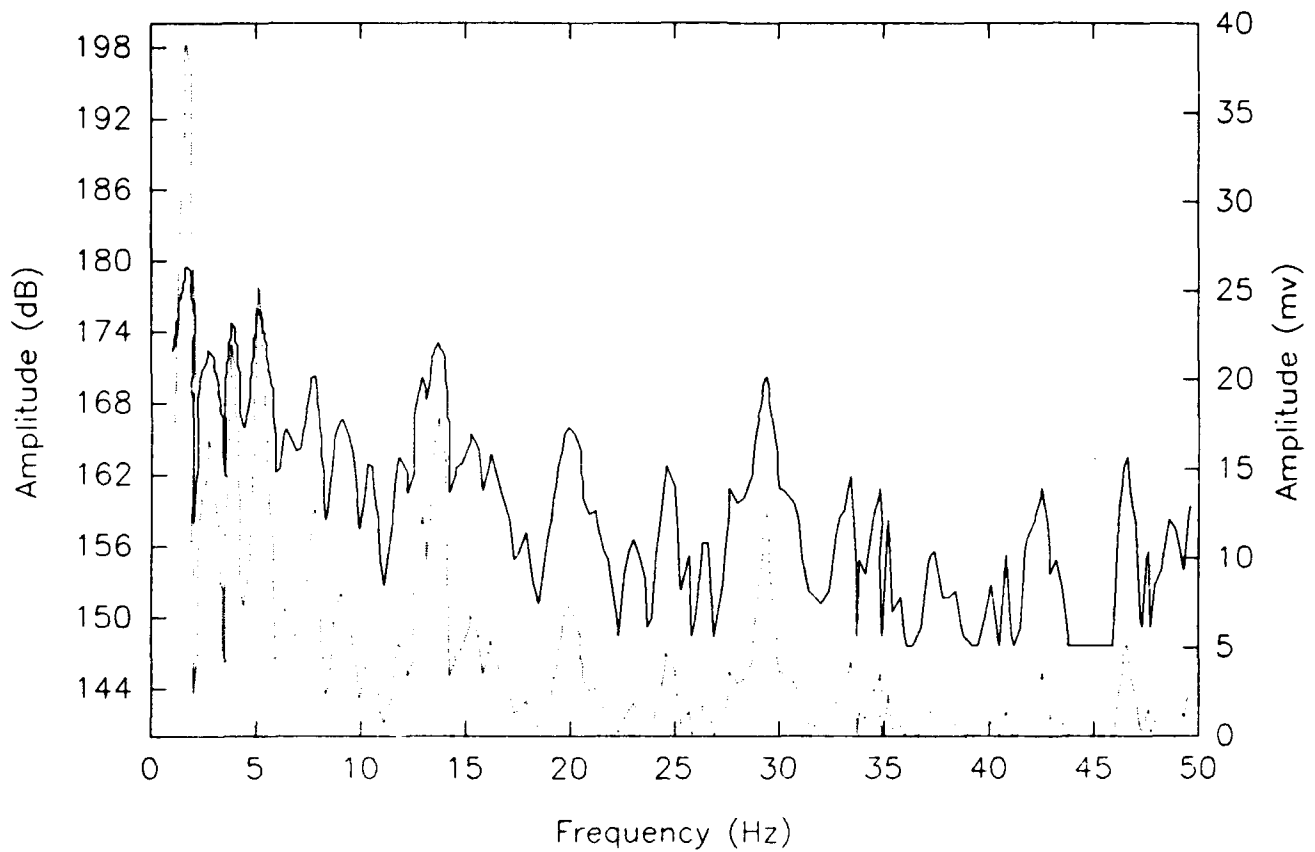in Kerr Dam Forebay

Figure 5. Ambient sound levels (dB = solid line; mv = dotted line)
and frequency spectrum in the forebay of John H. Kerr Dam,
May 1, 1990

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were about 3 to 1 at 0 to 7 Hz, 40 to 1 at 7 to 9 Hz, 7:1 at 9 to 25 Hz, and 40 to 1 at 25 to 50 Hz.

Most of the sound levels measured with a hydrophone at the front of the net pens during tests were reasonably close to theoretical sound levels. However, measured sound levels were 5 to 6 dB below theoretical levels in Tests 6 and 7, when the gun was positioned 8 to 9 m below the pens and adjacent to them (2.3 to 4.3 m horizontally).

One-minute tests

We found no significant changes in the distribution of striped bass among quadrants in the first minute of any test (Chi square test: $P > 0.05$), except in Test 6 (Chi square = 30.96; $P = 0.029$). However, 75 percent of the cells in the two-way contingency table (i.e., quadrant versus time) had expected counts less than 5. Two-way analysis of variance revealed no significant effect of time (5 to 40 sec after the gun was fired) on the distribution of fish in the net pens, and no significant time versus quadrant interaction. However, significant differences in the mean density among quadrants were apparent in one-way ANOVA's on Tests 1, 2, 4, 5, and 7 (no differences were observed in Tests 3 and 6). In the soundless control test, mean densities were significantly higher in Q2 (3.2) than in Q3 (2.2), and means in Q2 and Q3 were both significantly higher than those in Q4 (1.1) and Q1 (0.97), which did not differ ($P > 0.05$). In Test 2, densities in Q2 and Q3 (2.8 and 2.4, respectively) did not differ significantly, but both were significantly higher than those in Q4 (1.3) and Q1 (1.0). In Test 4, mean density in Q3 was significantly higher than means in the other three quadrants, which did not differ (1.4 to 1.9; $P > 0.05$). In Test 5, the mean in Q2 (2.7) was highest and differed significantly from those in Q3 (1.9) and Q1 (1.5), which were statistically similar. Means in Q1 and Q4 also did not differ ($P > 0.05$). In Test 7, means were ranked Q3

(1.3), Q2 (1.3), Q1 (1.0), and Q4 (0.7), but only means in Q3 and
Q4 differed significantly.

<u>Five-minute tests</u>

We detected no significant temporal changes in the
distribution of striped bass among quadrants with quadrant versus
time Chi-square tests that usually had expected counts >20. As
in the one-min tests, two-way analysis of variance for the 5-min
tests showed no significant among-time effect or time-quadrant
interaction, although the time-quadrant interaction in Test 7 was
nearly significant (P = 0.06). Mean densities by quadrant also
did not change significantly with time after firing. Changes in
mean density in Q3 during Test 7 were closest to being
significant (P = 0.20). Mean density was lowest immediately
before the gun was fired (0.85); it increased to 1.0, 10 sec
after firing, to 1.6, 15 to 20 sec after firing, and then
decreased to 1.3, 30 sec after firing, and to 0.8, 40 sec after
firing.

Although mean densities in individual quadrants did not
change significantly in the minute after the gun was fired,
consistent trends were apparent in Tests 2, 5, 6, and 7
(Figure 6). In general, mean density in Q1 decreased from 5 sec
before firing (5 sec after in Test 7) to 10 (Tests 2 and 6), 15
(Test 5), or 20 sec (Test 7) after firing. Means in Q1 generally
increased during the second half of the 40-sec period examined.
Slopes of regression lines fitted to all points from which means
in the descending arm of Figure 6 were calculated did not differ
significantly from zero due to high variability among replicate
samples.

Mean densities were significantly different among quadrants
even though densities in individual quadrants did not change with
time. In Tests 1 to 5, mean densities were significantly higher
in Q2 (2.4 ± 0.08) and Q3 (2.4 ± 0.16) than those in Q1 (1.4 ±
0.15) or Q4 (1.3 ± 0.32). In Test 6, mean densities in Q1 (1.6)
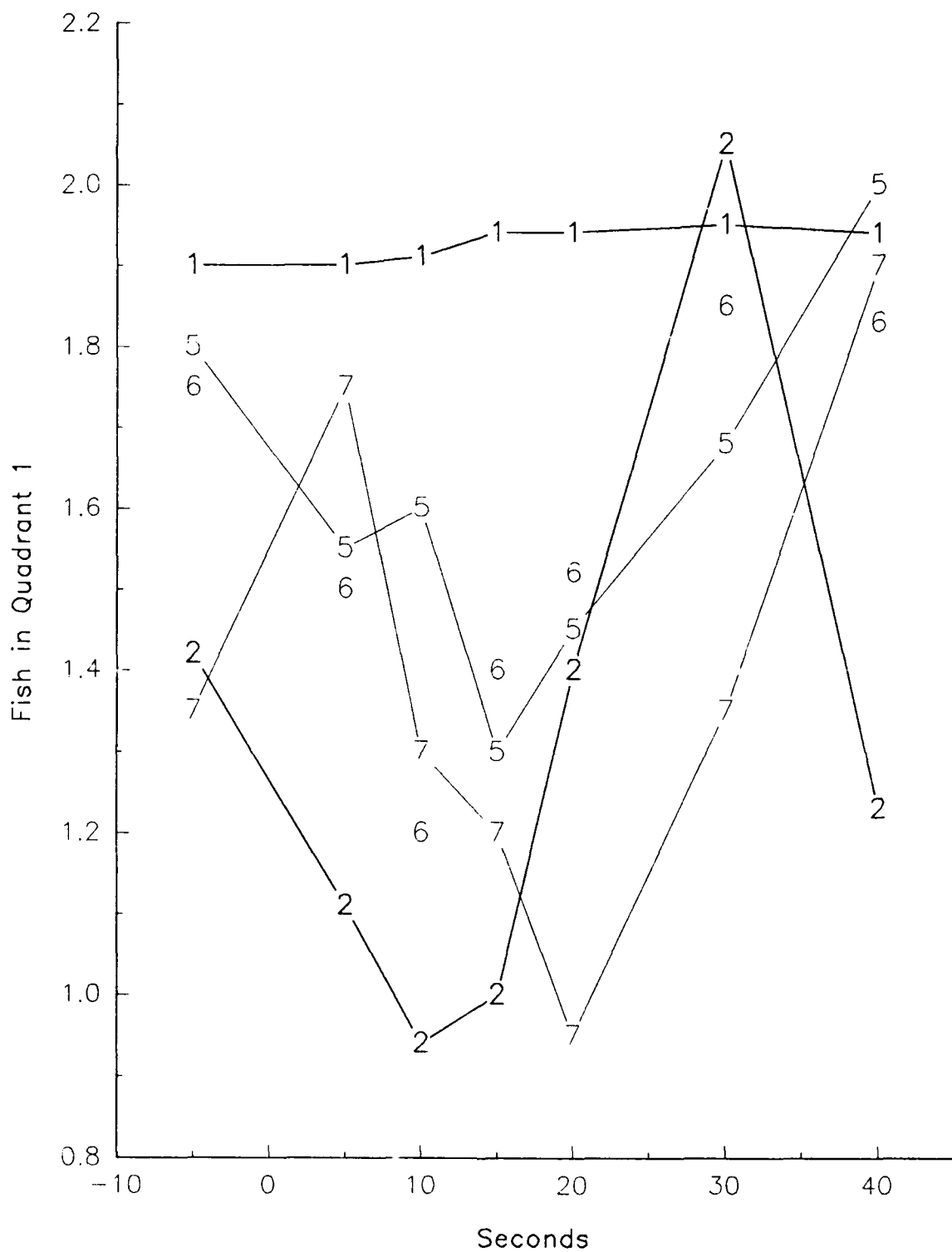and Q2 (1.4) did not differ (P > 0.05), but both were higher than

Figure 6. Mean densities of adult striped bass in quadrant 1 of
net pens (nearest the sleeve gun) from 10 seconds before
(−10) to 40 seconds after firing. Means are numbered
to indicate the test from which they were calculated.
Test 1 was the soundless control

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those in Q3 (1.2) and Q4 (0.6). Test 7 means were similar to those in Test 6: 1.4 (Q1), 1.4 (Q2), 1.2 (Q3), and 0.6 (Q4), but means in Q1 to Q3 did not differ significantly, whereas the Q4 mean was significantly lower than other means.

## Full tests

Results of full tests were similar to those presented for 1-min and 5-min tests. We found no significant changes in the distribution of striped bass among transects in up to 15 replicate samples of 1-min periods after sleeve gun firings. Chi square probabilities were closest to being significant in sleeve gun Tests 6 ($P = 0.12$) and 7 ($P = 0.11$). Mean densities in each quadrant did not change significantly in the minute after a sleeve gun blast. Means in Q1 in Tests 5 and 6 came the closest to exhibiting significant changes with time ($P = 0.056$ and $P = 0.107$, respectively). In Test 5, mean density in Q1 was lower ɔ to 15 sec after blast time (1.71 to 1.75) than the mean 5 sec before blast time (1.93), although not significantly. Mean density in Q1 then gradually increased to 1.96 at 20 sec after a blast, to 2.18 at 30 sec after, and to 2.41 at 40 sec after. A similar pattern was observed in Test 6 (Figure 7). These findings prompted us to reanalyze the data using only densities estimated in the first 15 to 20 sec after the gun was discharged. However, no significant temporal changes in density in any quadrant were detectable by regressing density on time.

Observers noted some startle responses from striped bass when the sleeve gun was fired in the first few seconds of a test. However, this minimal response diminished during prolonged tests. In Tests 6 and 7, the movement of fish in pens was increased over what we observed in earlier tests.

## Discussion

We associated increased movement of fish in Tests 6 and 7 with increased circulation of cool water in the pens as bubbles rose from the gun past or through the first quadrant of the pens. Bubbles from a blast required 4 to 5 sec to reach the surface
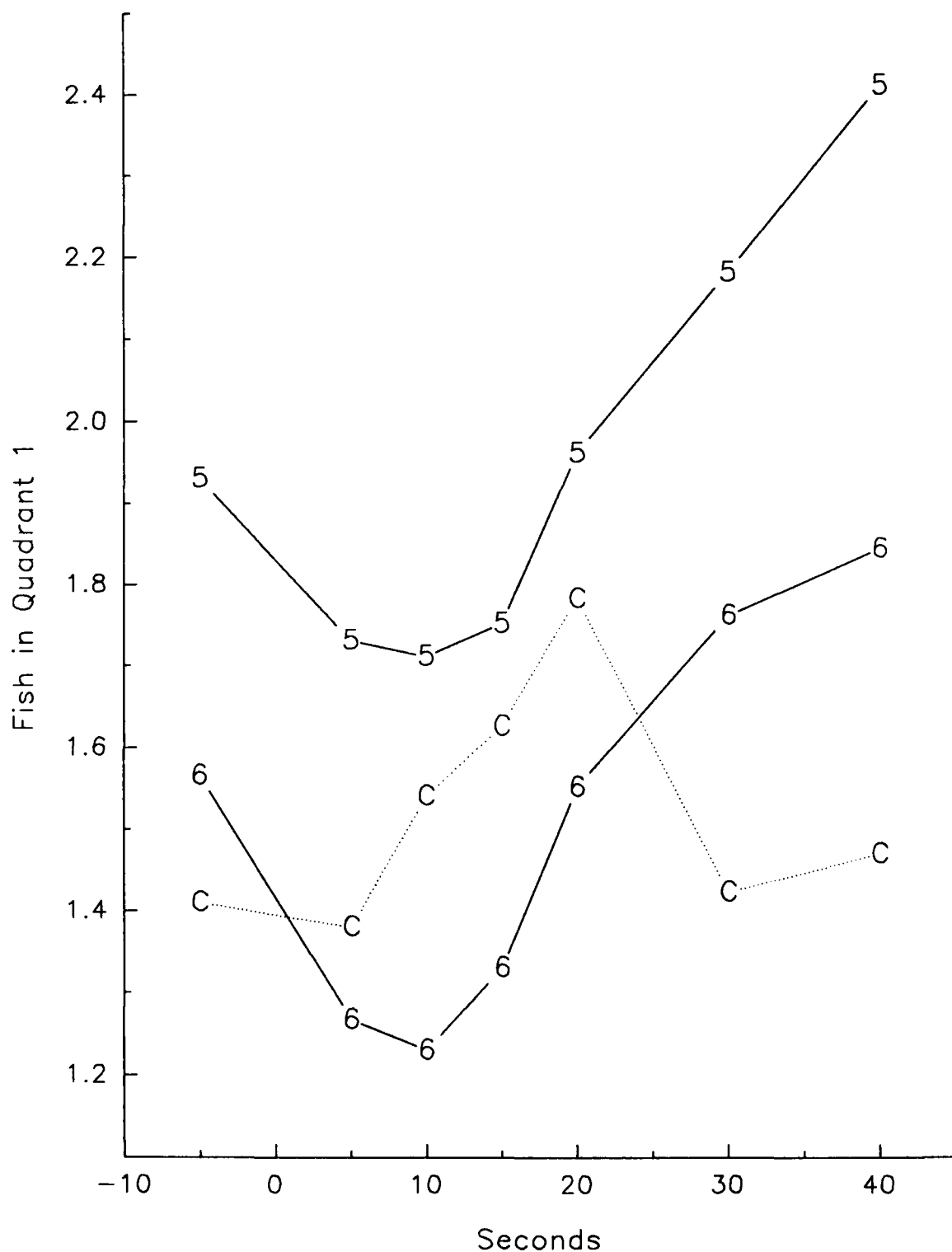
Figure 7. Mean densities of adult striped bass in quadrant 1 of net pens (nearest the sleeve gun) from 10 seconds before (−10) to 40 seconds after firing. Means were from the control (C), Test 5 (5), and Test 6 (6)

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from depths of 8 to 9 m and would have forced cooler water to the surface adjacent to the pens.

The evolution of the experimental design from Tests 1 through 7 reflects our attempt to eliminate perceived design deficiencies that may have resulted in the non-response of striped bass to sounds produced by the sleeve gun. In Tests 3 and 4, we changed the frequency spectrum of peak sounds by increasing pressure from 1,500 to 2,000 psi (Test 3) and 1,875 psi (Test 4). Peak source levels remained about the same amplitude but occurred at different frequencies. Tests 5 to 7 were conducted at 1,500 psi but in deeper water because we were concerned that sound was being attenuated by contacting the bottom. The bottom may attenuate a sound wave of a given frequency or less if water depth is less than one quarter the wavelength of the sound.

Consequently, in water 10.6 m deep (Tests 1 to 4), sound intensities for frequencies of 35.4 Hz and less (wavelength $\geq$42.3 m) may have been less than they would have been in deeper water. Intensities for frequencies $\leq$14 Hz may have been selectively attenuated in water 26.8 m deep (Tests 5 through 7). In Tests 6 and 7, the depth of the sleeve gun was increased from 5 to 9 and then 8 m and the pontoon boat deploying the gun was moved to within 4.3 m of the pens. The concern with firing at 15.2 m away and 5 m deep was that reflections from the water's surface (180 deg out of phase) were canceling sounds moving directly at fish in the pens. Our change was an attempt to assure that sound waves from the gun reached the striped bass before they could strike the surface and reflect out of phase.

The closeness of most sound levels measured at the front of the net pens to post-experiment calculations of expected levels (Table 1) suggests that most of the concerns described in the previous paragraph were minor. It is likely that amplitudes measured in Tests 1 to 4 were mostly at frequencies above 25 Hz because of water depth (10.6 m). Some of the lower than expected

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sound levels in Tests 6 and 7 may have been caused by sound attenuation as it passed through the bottom frame of the nets. The bottom frame was covered with bolting cloth, but it seems unlikely that the cloth alone could cause a halving of sound intensity. The sleeve gun is omni-directional so the position of the gun relative to the pens should not affect sound intensity at the pens, unless something between the gun and pens interferes with sound transmission.

Behavioral observations and statistical analyses indicated that adult striped bass in the 20-ft long pens exhibited only subtle and inconsequential responses to sounds produced by a 150-cm$^3$ sleeve gun. Startle responses were only apparent early in tests, and fright responses, that would have been suggested by increased swimming speeds or strong directional movements away from the sound source, were never observed.

Statistical test results support qualitative observations of fish behavior. We detected no significant temporal changes in the distribution of striped bass among quadrants with Chi square tests that had expected counts of >20 per quadrant-time cell. We question the validity of the single significant Chi-square test on the first minute of Test 6. Chi-square tests may be inappropriate when 75 percent of the cells have fewer than five counts. Two-way analysis of variance showed no significant among-time effect or time-quadrant interaction. Mean densities by quadrant also did not change significantly with time after the gun was fired.

We believe that movements of adult striped bass in response to sounds from the sleeve gun were constrained by the size of the pens relative to the size of the fish. The length of most specimens was 11 to 12 percent of the length of the pens and 54 to 61 percent of the width. We would not have expected more dramatic responses to sleeve gun blasts in a larger pen or in open water, but fish would have been free to move farther away from the sound source thereby facilitating our identification of

significant changes in distributions. Figures 6 and 7 may be indicative of constraints of net size on movements of fish. In the first half of the 40-sec period fish densities in Q1 generally declined whereas they increased for the most part 20 to 40 sec after a blast. The decline may not have been more apparent than what we observed, but second half increase may not have occurred if fish had not been limited by the end of the pen 16 to 18 ft away. On several occasions in every test, we observed some fish repeatedly moving from one end of the pens to the other.

The distribution of fish at specific time intervals after a blast undoubtedly was influenced by the location of a fish at the time of the blast. For example, a fish in Q1 may well startle and move slowly away from that quadrant, whereas one in Q4 may startle and move into Q3 or Q2 because it cannot move further away from the sound source. These limitations could easily influence the outcome of statistical tests. Further testing of sleeve gun in a net pen of the size used does not seem warranted given that only minor changes in swimming rates were observed after the gun was fired.

Repelling adult striped bass with low-frequency sounds may be possible, but the lack of a strong startle response in our tests suggests that a sleeve gun is not a probably technology, although we have not conclusively demonstrated that it will not work. Low-frequency sounds have been used successfully to repel many species of fish but varying responses apparently are species and size or age specific. We tested the sleeve gun because it was relatively inexpensive and produced low-frequency sounds that NYPA found to be effective in repelling juvenile white perch and striped bass. These frequencies apparently are less effective on adult striped bass than on young of year. We observed young-of-year clupeids jumping from the water immediately after sleeve gun blasts but observed no comparable response from adult striped bass. The frequency spectrum of sound made by the sleeve gun

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(mostly < 50 Hz) was below most frequencies (60, 120, 240, 360, 720 Hz) that Loeffelman (1990) found to be effective in reducing fish densities at the Racine Project on the Ohio River.  Although Loeffelman found statistically significant differences in density of many fishes in areas with and without sound, his electronic equipment did not obtain complete exclusion of fish and required tuning of sounds for different species.  The tuning process and size of the area to be protected at Kerr Dam could make this technology expensive to implement at Kerr Dam.  Unfortunately, neither NYPA or Loeffelman have had the opportunity to test adult striped bass.

## Recommendations

Further attempts to evaluate low-frequency sound systems or other methods of deterring striped bass passage through Kerr Dam should be postponed until the magnitude of the problem has been assessed.  If sound-based evaluations are resumed, the design of net pens must be changed to allow these large fish greater freedom of movement so that the consequences of even subtle responses can be adequately evaluated.  Another system of producing low-frequency sounds should be considered so that many frequency ranges can be tested separately.  If adult striped bass respond to a mixture or narrow range of low frequency sounds, these sounds will only be identified by testing a sound system with more sound-production flexibility than a sleeve gun.

## References

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